VEGETATION OF THE UPPER RAIDER AND HORNBACK CREEK BASINS, SOUTH WARNER MOUNTAINS: NORTHWESTERN LIMIT OF *ABIES CONCOLOR* VAR. *LOWIANA*

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ABSTRACT

This study identifies the different plant communities and describes the forest stand structure in 2400 hectares of the upper Raider and Hornback Creek basins on the eastern slope of the South Warner Mountains in Modoc County, California. Major plant communites were estimated using aerial photography and ground reconnaissance. The predominant community in the study area was found to provide an example of a large contiguous stand (575 ha) of *Abies concolor* var. *lowiana* at the northeastern extreme of its distribution in California. Community structure was obtained from the point-centered quarter method and nested quadrats. Other plant communities identified were: Mountain Mahogany Scrub, Montane Meadows, Subalpine Sagebrush Scrub, Northern Juniper Woodland, Big Sagebrush Scrub, Whitebark Pine Forest, Washoe Pine-White Fir Forest, and Riparian Forest.

Few studies of the vegetation have been made within the Warner Mountains of northeastern California, and of those conducted, most have emphasized the vegetation of the western slopes or summarized habitat types (Pease 1965; Milligan 1969; Rundel et al. 1977; Vale 1977; Riegel 1982; Riegel et al. 1990). The vegetation of the eastern slopes of the Warner Mountains is less well-known. This study identifies the different plant communities present in a 2400 hectare area on the eastern exposure of the Warner Mountains. We also describe the structure of the dominant vegetation within this area, a large, relatively uncommon example of an undisturbed stand of mature *Abies concolor*. Here we hope to provide a framework for future ecological research regarding the regeneration and distribution of *A. concolor* as well as provide descriptive information about this understudied area.

Abies concolor is recognized as the dominant forest species in the Warner Mountains (Vale 1977; Riegel et al. 1990). However, much

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of the research conducted on white fir forests has been in the Sierra Nevada (Rundel et al. 1977; Conard and Radosevich 1982) with a few studies in the desert ranges of southern California (Vasek 1985). Based on existing research, *A. concolor* is found at mid-elevations both as a component of mixed conifer forests and in pure stands throughout its range. In northern California, white fir stands are frequently found at intermediate elevations between mixed conifer forests and red fir forests (Griffin 1967).

Abies concolor is shade-tolerant and, in the absence of fire, has become the climatic dominant over large acreages in Oregon and California. Mature stands of *A. concolor* have a closed canopy and very little understory vegetation. Stands are typically even-aged, with >80% of the overstory *Abies concolor* (Rundel et al. 1977; Shimamoto 1988). Understory associates are variable over the wide geographic range of the type.

Two varieties of *Abies concolor* have been recognized over the wide range of this species: *Abies concolor* var. *lowiana* in the Sierra Nevada and northeastern California, and *A. concolor* var. *concolor* in the Rocky Mountain region (Hamrick and Libby 1972). The Warner Mountain stands are among the largest, northeastern-most populations of *A. concolor* var. *lowiana* (Critchfield and Allenbaugh 1969).

Study Area

The Raider and Hornback Creek basins are located about 2.5 km northwest of Eagleville, California in the South Warner Wilderness Area within the Modoc National Forest (Fig. 1). The study area roughly delineated, comprises the upper watersheds of Raider and Hornback Creeks and occurs in Sections 3, 4, 8–10, and 15–22, Township 40 North, Range 16 East, Humboldt Base and Meridian, the Eagle Peak 7.5 minute quadrangle, Modoc County, California. The elevation of the study area ranges from 1480 m at the western edge of Surprise Valley to 2775 m at the top of Dusenbury Peak.

The Warner Mountains are a north–south block mountain range of the Modoc Plateau, formed as a result of dip-slip faulting (Oakeshott 1971). The Surprise Valley fault escarpment rises 1500 m above Surprise Valley and forms the eastern slope of the Warner Mountains. The eastern border of the South Warner Wilderness area generally follows the base of the escarpment.

Four major soil associations are present within the study area, with the Waca–Lyonman association supporting the majority of the vegetation. This deep and moderately deep well-drained soil in steep or strongly sloping areas supports *Abies concolor* and associated conifers (Camilleri 1979; Sheldon 1980). At lower elevations, the Homecamp–Newlands association is composed of stony and dark grayish brown loams and supports *Artemisia tridentata* and asso-

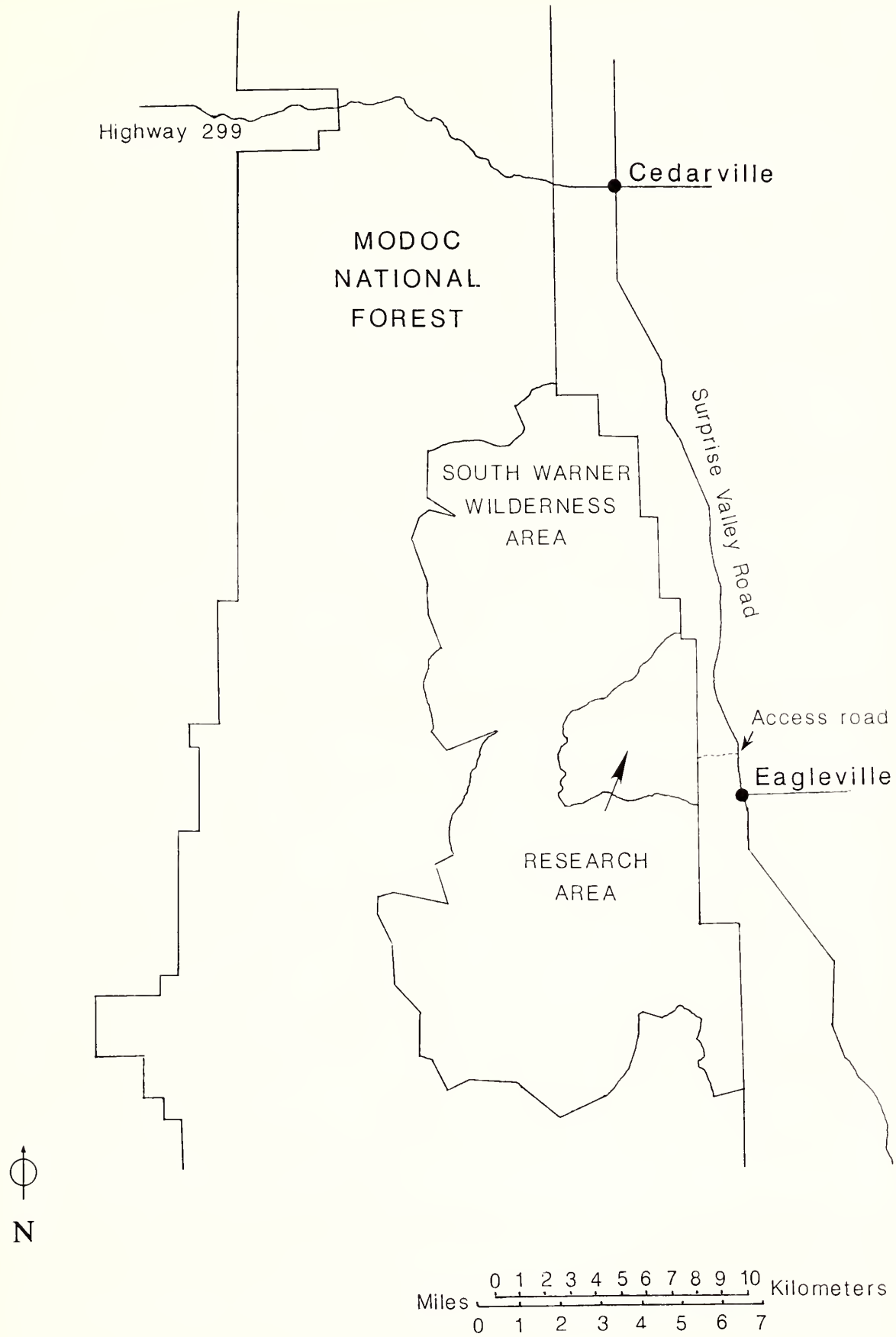

FIG. 1. Map of study area in the upper Raider and Hornback Creek drainages, South Warner Mountains, Modoc National Forest, California.

ciated bunch grasses. The Hapgood–Snag association consists of deep, well-drained soils on mountain slopes and in small basins. It is comprised of dark grayish brown stony loam and gravely fine sandy loam over tuff and very stony fine sandy loam over slightly weathered basalt. The Hapgood–Snag association also supports *Artemisia tridentata* and various bunch grasses. The rocky outcrops and steepest portions of the study area are classified as the Rubbleland-Rock Outcrop association. Vegetation is sparse in these areas (Sheldon 1980).

The climate of the Warner Mountains is influenced both by precipitation patterns of coastal California and cold winter temperatures of the northern continental United States. These influences result in a climate of cold humid winters and virtually rainless, short, mild summers (Pease 1965). The annual precipitation in the study area is approximately 51 cm, the majority of it falling from September through mid-June in the form of snow. Winter days in which precipitation falls alternate with those that are extremely cold and dry. Dry thunderstorms are common during late May, June, and July, and occur on 20 percent of the days (Pease 1965). The mean January temperature of the eastern slope of the Warner Mountains is estimated to be −6.6°C, and the mean July temperature 15.5°C (Pease 1965).

Grazing and fire disturbances to the study area have been limited. Modoc National Forest personnel have no knowledge of any fire within the study area in the last 95 years (S. Smith personal communication). The Raider Creek basin was grazed by sheep until 1943 and by cattle from 1943 to 1971. The study area has had little use as a grazing allotment since 1971, although sheep allotments have been used in adjoining Owl and Mill Creek basins and some animals may have wandered into the Raider and Hornback Creek basins (Camilleri 1979). A lack of access to an adjoining cattle allotment due to storm damage required the movement of cattle through the study area in 1987. Cattle use of the Raider Creek trail in 1987 was authorized on a one-time basis (M. Yamagiwa personal communication). Although we found some evidence of erosion due to trampling at lower elevations outside of the study area, there was no apparent grazing related damage to vegetation within the study area.

Methods

The forest vegetation was sampled along four transects in the Raider Creek basin during August 8–14, 1988. Transect location was chosen following visual reconnaissance and aerial photograph examination to obtain the best representation of vegetation throughout the stand. Transects were evenly spaced approximately 1 km apart throughout the basin; precise locations can be found in Jensen and Schierenbeck (1989). Point-centered quarter method (Cottam

and Curtis 1956) was used to determine frequency, density, and basal area of the overstory trees. At 10 m intervals, distance and diameter at breast height (dbh) were measured for four trees at each of 21 points along three transects; a fourth transect had only 11 points. Running means were calculated along each transect to determine sampling adequacy (Mueller-Dombois and Ellenberg 1974). Only those trees >2 m in height were counted in the overstory. Percent cover and frequency were measured in nested plots. The shrub stratum was sampled at each point using a 4 m^2 grid, randomly assigned to the right or left of the transect line. Herbaceous vegetation was sampled at each point using a 1 m^2 grid.

The extent of each plant community was determined using stereo aerial color photography (1:25,000) in conjunction with the results of quantitative sampling and qualitative field observations. Acreage was estimated using a dot grid area scale.

One classification system does not currently exist for all communities we surveyed. Holland (1986) provided the most comprehensive alternative, except for those forest stands dominated by *Abies concolor.* Hence, we refer to stands dominated by *A. concolor* as White Fir Forest (Society of American Foresters 1954), while the remaining plant communities are classified according to Holland (1986).

Plant species were identified in the field when possible. Voucher specimens were collected of all species for which field identification was questionable. Nomenclature follows Munz and Keck (1968). Diploxylon pines (*Pinus jeffreyi* and *P. washoensis*) could not always be accurately separated, particularly when cones were not present. *Pinus jeffreyi* and *P. washoensis* are known to hybridize and there is some controversy over the distribution of these species in the Warner Mountains (Haller 1961; Riegel et al. 1990). When in doubt, we refer to all diploxylon pines as *Pinus jeffreyi/washoensis.*

Results and Discussion

The results from qualitative observation and interpretation of the aerial photography indicate White Fir Forest is the most abundant vegetation type in the study area; over 575 hectares of the study area are dominated by *Abies concolor.* At the lower elevations, the *Abies concolor* dominated canopy intergrades with mature individuals of either *Pinus jeffreyi* or *P. washoensis.* At higher elevations, the canopy intergrades with *Pinus albicaulis* and *Pinus monticola.* Much of the study area below 1768 and above 2377 meters consists of rocky exposed volcanic tuff barren of vegetation. Plant communities present in addition to White Fir Forest are described in Table 1.

In the forest transects, *Abies concolor* far surpassed the other conifer species in frequency, density, and cover (Table 2). Of 293 trees measured, 266 were *Abies concolor,* 12 *Pinus albicaulis,* and 15 *Pinus*

TABLE 1. VEGETATION TYPES IN THE RAIDER AND HORNBACK CREEK BASINS, SOUTH WARNER MOUNTAINS, MODOC NATIONAL FOREST, MODOC COUNTY, CALIFORNIA.

Vegetation type	Topographic limits	Area (hectares)	Dominant species	Associated species
Big Sagebrush Scrub	1820–2120 m on exposed se facing slopes	73 ha	*Artemisia tridentata* *Purshia tridentata*	*Agropyron spicatum* *Bromus tectorum* *Festuca idahoensis* *Stipa occidentalis* *Oryzopsis* spp.
Northern Juniper Woodland	1646–2012 m on exposed slopes	145 ha	*Juniperus occidentalis* ssp. *occidentalis*	*Artemisia tridentata* *Purshia tridentata*
Washoe Pine-White Fir Forest	generally below 1981 m	16 ha	*Pinus jeffreyi/ washoensis* *Abies concolor*	*Artemisia tridentata*
Montane Black Cottonwood Riparian Forest	along Raider and Hornback creeks above 1600 m	limited	*Populus trichocarpa*	*Pinus jeffreyi* *Prunus emarginata* *Rosa woodsii* *Salix scouleriana*
Montane Riparian Scrub	limited to high elev.	as stringers in rocky drainages	*Salix scouleriana*	*Veratrum californicum* *Carex microptera* aff.
Mountain Mahogany Scrub	dry south facing slopes, exposed ridges	94 ha	*Cercocarpus ledifolius*	*Juniperus occidentalis* *Artemisia tridentata* *Balsamorhiza sagittata* *Amelanchier pallida* *Artemisia arbuscula* *Chrysothamnus nauseous* *Ribes cereum*

TABLE 1. CONTINUED.

Vegetation type	Topographic limits	Area (hectares)	Dominant species	Associated species
Montane Meadows	along creek branches in level or gently sloping terrain	73 ha	*Veratrum californicum*	*Agrostis exarata* *Deschampsia caespitosa* *Carex microptera* aff. *Elymus glaucus* *Epilobium* sp. *Frasera speciosa* *Glyceria elata* *Hordeum brachyantherum* *Hypericum anagalloides* *Lupinus polyphyllus* ssp. *superbus* *Populus tremuloides* (above 2120 m) *Potentilla gracilis* *Trifolium cyanthiferum* *Veronica americana*
Subalpine Sage Scrub	intermittent at high elevation barren areas	sporadic on barren areas	*Artemisia arbuscula*	*Arenaria aculeata* *Sedum stenopetalum* *Eriogonum caespitosum*
Whitebark Pine Forest	above 2317 m	approx. 104 ha as pockets	*Pinus albicaulis*	

TABLE 2. FREQUENCY, DENSITY, AND DOMINANCE AND IMPORTANCE VALUES OF TREES IN THE UPPER RAIDER CREEK BASIN.

Species	Absolute frequency	Density (trees/100 m^2)	Dominance (cm^2/100 m^2)	Relative density	Relative dominance	Relative frequency	Importance value
Abies concolor var. *lowiana*	100%	5.35	6918.84	91.6%	94%	74%	260.6
Pinus jeffreyi	19%	0.25	375.47	4.2%	5.1%	14%	23.3
Pinus albicaulis	15%	0.23	68.98	3.9%	0.9%	11%	15.8

TABLE 3. FREQUENCY AND COVER DATA FOR HERBACEOUS SPECIES FOUND IN 1 M^2 QUADRATS, IN WHITE FIR STANDS IN THE UPPER RAIDER CREEK BASIN.

	Transect 1	Transect 2	Transect 3	Transect 4
Percent of quadrats with herbaceous vegetation	57	19	67	60
Average percent cover	3.9	0.2	5.5	7.0
SPECIES PRESENT				
	Frequency percentage		Relative frequency	Cover
ALL TRANSECTS				
Abies concolor (seedlings)	4.0%		3.0%	0.6%
Adenocaulon bicolor	1.0		1.0	0.3
Amelanchier pallida	1.0		1.0	3.3
Arnica cordifolia	20.0		16.0	14.6
Berberis repens	3.0		2.0	1.0
Collinsia parviflora	3.0		2.0	1.6
Geranium sp.	1.0		1.0	0.3
Grass-unknown	20.0		16.0	15.3
Hieracium albiflorum	15.0		12.0	15.6
Kelloggia galioides	4.0		3.0	2.7
Linanthus nuttallii	3.0		2.0	0.6
Lupinus caudatus	5.0		4.0	6.6
Onagraceae-unknown	1.0		1.0	0.3
Osmorhiza chilensis	4.0		3.0	3.3
Penstemon gracilentus	12.0		9.0	8.3
Poa pratensis	8.0		6.0	5.5
Polygonum sp.	3.0		2.0	0.7
Pyrola picta	8.0		6.0	1.7
Silene douglasii	1.0		1.0	0.3
Sitanion hystrix	5.0		4.0	2.3
Solidago canadensis	5.0		4.0	13.6
Trifolium wormskioldii	1.0		1.0	1.0
TOTAL	128		100	99.5

jeffreyi/washoensis. Basal area of *A. concolor* ranged from 30 m^2 per hectare to 106 m^2 per hectare. All but three of the saplings or seedlings sampled were *A. concolor.*

The stands we sampled could be assigned to the *Abies concolor/ Osmorhiza chilensis* habitat type described by Riegel et al. (1990). Canopy cover was nearly exclusively *A. concolor.* The herbaceous vegetation, characteristic of the habitat type, was very sparse. Rundel et al. (1977) reported understory cover in mature White Fir forests was seldom greater than 5 percent; measured herbaceous understory cover in Raider Creek basin ranged from 0.2 to 7 percent (Table 3). Species that occurred with high frequency in the herbaceous quadrat samples included *Arnica cordifolia, Hieracium albiflorum, Penstemon gracilentus, Osmorhiza chilensis,* and *Kelloggia galioides.*

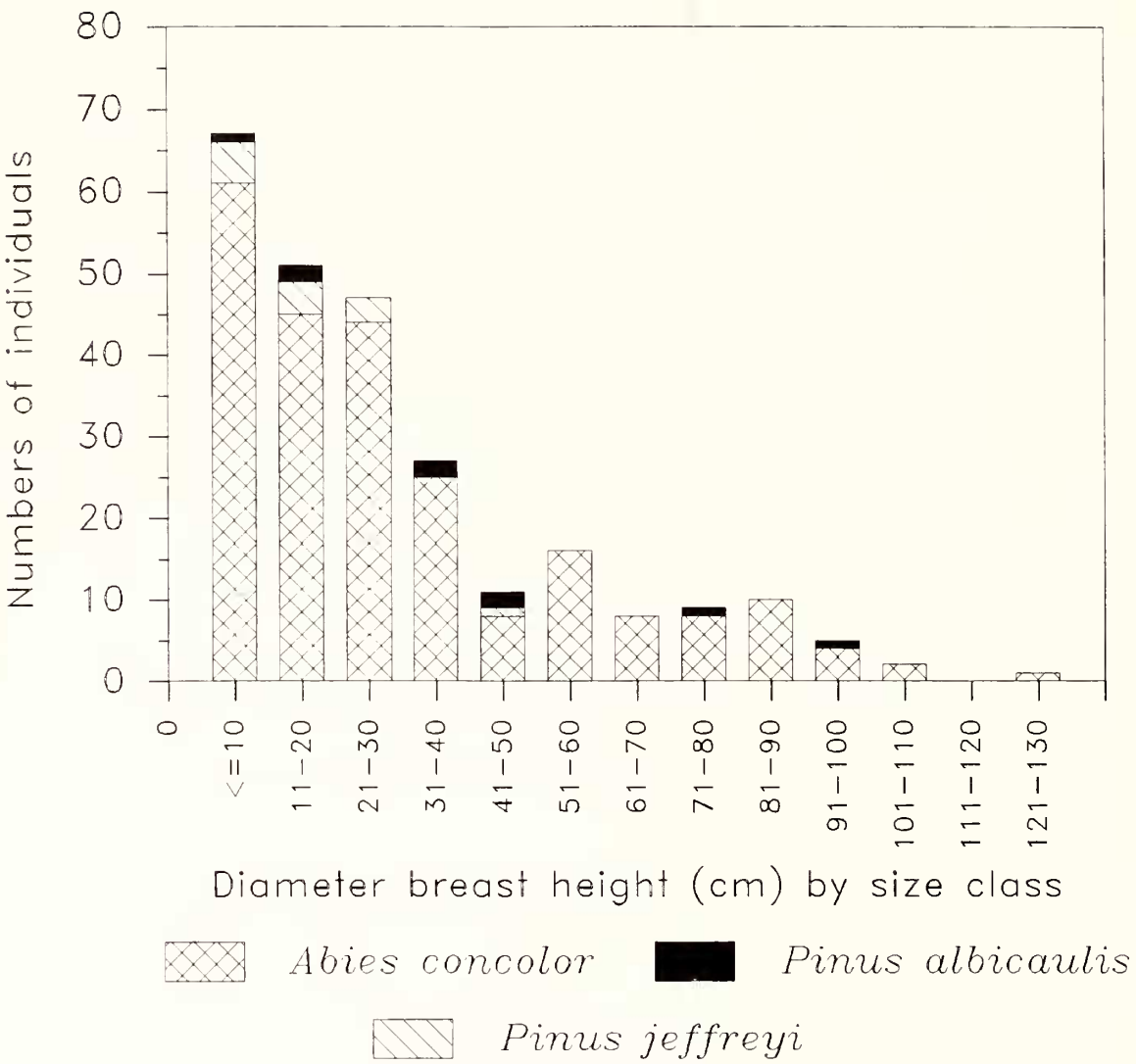

FIG. 2. Size-frequency histograms of trees in the upper Raider Creek drainage.

Shrubby understory species were uncommon; 0.7, 0, 3.5 and 1.8 percent cover in the four transects, respectively (Table 3). The most common shrub species present was *Cercocarpus ledifolius.* Of the 177 plant species identified or likely to occur in the upper Raider and Hornback Creek basins (Jensen and Schierenbeck 1989), only 26 occurred in any of herb or shrub quadrats. Due to the elevational and topographic diversity and array of relatively undisturbed vegetation types within the study area, the flora of this often overlooked geographic region deserves more exploration.

Although the relationship between size and age in this study is unknown, size-frequency plots indicate that all of the stands show continuous regeneration and thus appear to be climax types (Fig. 2). The variation in size distributions may indicate that some portions of the basin contain older stands with less recruitment, while others have fewer large individuals and abundant recruitment. Although speculative, portions of the basin may have burned before the 1900's, while other stands were untouched. The size-frequency distribution

would be consistent with the scenario that the White Fir Forest of the Raider Creek basin is an aggregation of small stands that exist in a shifting mosaic of steady state reproduction (Pickett and White 1985). Alternatively, the reverse-J-shaped distribution by size classes may indicate a very old stand consisting of trees which die on a regular basis, release growing space and thus allow stems to invade at a uniform rate (Oliver and Larson 1990). Further research is necessary to determine the disturbance history and extrinsic factors which influence the dynamics of the basin vegetation.

Conard and Radosevich (1982) suggest that in the Sierra Nevada, mature stands of fire intolerant *A. concolor* are restricted to mesic sites with a low fire frequency. Despite the xeric nature of this site (Fowells 1965 reports 88.9–190.5 cm of annual water equivalent is typical for white fir stands), white fir is successfully reproducing. Lack of any recent large scale fire disturbance is supported by the low numbers of the more fire tolerant diploxylon pines. It is unclear whether the few diploxylon pines in the mid-elevation areas of the basin will remain in the continued absence of fire, with the possible exception of steep xeric slopes with low canopy cover of *Abies concolor*. The effects of the absence of fire and extensive grazing on the regeneration and structural composition of White Fir Forests await study in this area. Additional possibilities exist in the exploration of these individuals of *Abies concolor* var. *lowiana* as genetic resources for more xeric growing conditions.

The example of White Fir Forest in the upper Raider Creek basin is a mature, well-developed example of the type and offers a rare opportunity to study the ecological dynamics of *Abies concolor* without the influence of broadscale human or natural disturbance. Little quantitative data exist on White Fir Forests in California and it is our hope that the descriptive information provided here will serve as a backdrop for further research on their structure and reproduction.

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